



turbed by management activities and fairly undisturbed by the many species of non-native plants and animals. This information can guide us as to what elements of biodiversity can be protected and restored, in what levels of abundance, and in what geographic areas, helping us reach our goal of sustainable ecosystems in the context of today's landscape.

What follows is an overview of ecological simplification, fragmentation, and environmental pollution, with an emphasis on explaining what these concepts mean and how they impact biodiversity. The concept of scale provides a foundation for understanding how to deal with these issues (see inset).

## SCALE

*Scale* is the relative amount or degree of something, often expressed in terms of a progressive classification as to size, complexity, or importance. In management of natural resources, scale is often used to describe the scope of a management action—whether site-specific, local, regional, or statewide in space, and annual, seasonal, or successional in time—and the degree to which the management action alters the existing plant and animal communities.

Thus, when the concept of scale is applied to ecosystems, it has both spatial and temporal meanings. *Spatial scale* is used to describe the geographic size of a community or ecosystem (Fig. 3). This size can range from a microsite such as the underside of a leaf on the forest floor, to the entire forest, to the larger landscape. The biosphere, including earth, its enveloping air mass, and all its biota can be thought of as the largest scale from a biological point of view. *Temporal scale* describes the time required to complete a life history event or an ecological process, such as the a series of successional stages (Fig. 4). For life history events such as life cycles, temporal scale can vary from a few hours for certain microbes and insects to thousands of years for ecosystems. Ecological processes can vary from a few seconds for individual biochemical reactions to decades for forest regeneration. When tied to geologic changes, temporal scale reaches millions of years.

For ecological purposes, the amount of detail with which an ecosystem can be described for management planning is determined by the spatial and temporal scales. Due to time and resource constraints, we are often able to provide more detail at smaller scales than at larger scales. We often speak of this situation using the term resolution, i.e., as having a high degree of resolution at small scales and a low degree of resolution at large scales. For example, in an endangered plant inventory of a very small plot, we may be able to thoroughly sample the plot inch-by-inch. An inventory of a large area would be done at a lower degree of resolution, perhaps by running transects at intervals across the area. The former sampling approach gives us a lot of information about a very small area, and the latter gives us less detail but includes a wider geographic area and a larger amount of total information on plant distribution.

The desired spatial scale for overall *ecosystem management* planning is the *landscape*. A landscape is an area composed of interacting ecosystems that are related due to underlying geology, landforms, soils, climate, biota, and human influences. Broad management goals will be set at this scale and will relate to relatively large geographic areas, using the information collected with a low degree of resolution, or less detail, as described above. Management of specific sites within the broad landscape

will occur based on goals set at the landscape scale. Information with a high degree of resolution will be collected at specific sites as needed to check the accuracy of goals set on the landscape scale or to fine-tune management plans for specific sites.

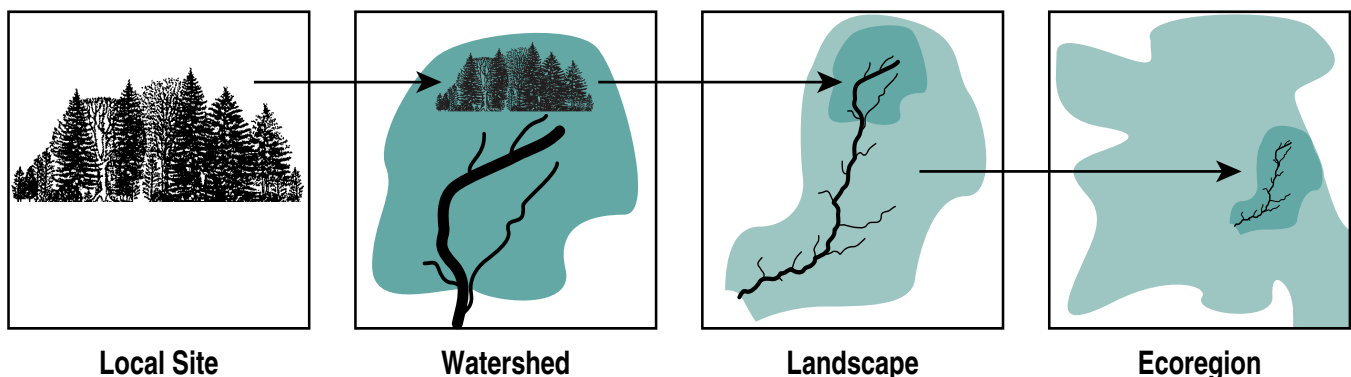
*Landscape-scale* management encourages us to approach problems and projects using the broadest scale with ecological meaning. Thus, the geographic area or *region* included in any particular analysis will be determined by our knowledge of the breadth of the interconnections among the biotic communities involved. For example, a proposal to create a new Natural Area in Wisconsin for the protection of biodiversity would include a series of considerations—among these are the size and quality of adjacent buffer areas needed to protect ecological integrity on the site; the relative importance of the site to biodiversity within a statewide view of community and ecosystem status; and concerns such as the transport of pollutants or the condition of migratory bird habitats on continental or inter-continental scales. Or, a proposal to acquire land to support an anadromous sport fishery on the Great Lakes

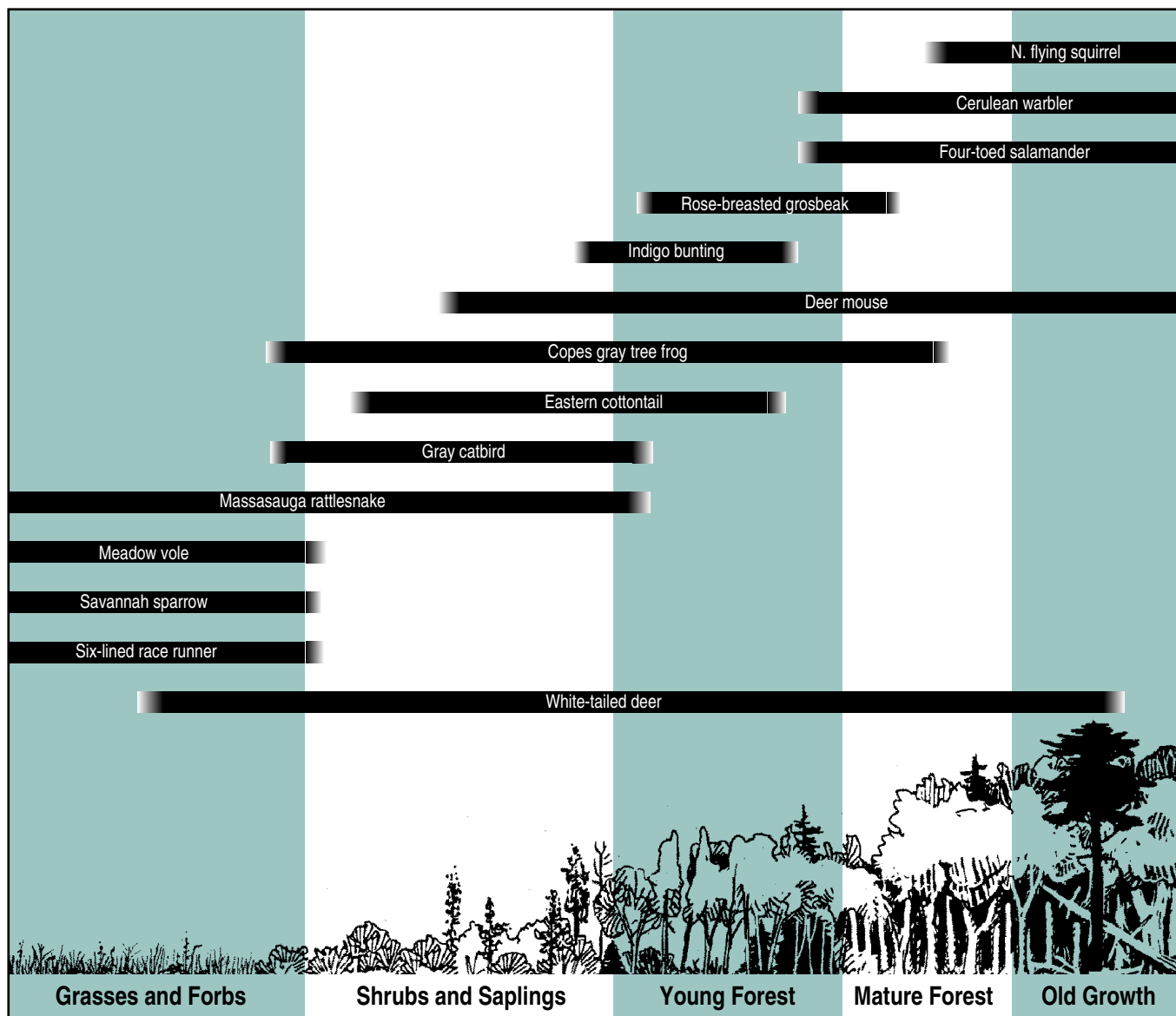
would include an analysis of the ecological conditions of all the streams and watersheds on the Wisconsin shoreline of Lake Michigan and/or Superior. The analysis would indicate how the overall management plans for these streams address statewide issues of biodiversity as well as other important related issues such as recreation and water quality.

Biodiversity is maintained by the presence of an array of communities and species occurring within ecosystems which are intact and sustainable, that is, they usually contain a wide range of species and natural processes. The appropriate scale for management must be considered and deliberated along with other considerations if biodiversity is to be preserved or enhanced. If we are not aware of the concept of scale in planning a proposed action or do not understand the implications of our choice, we run the risk of developing inappropriate plans and prescriptions. Worse, we can unknowingly change the community or ecosystem involved. These choices are complex, for decisions that favor increasing diversity at a given scale may decrease diversity at other scales.

**Figure 3**

Examples of spatial scales can be observed with the “nesting” of small areas, such as a local site, within progressively larger geographic units.





**Figure 4**

Examples of temporal scale can be observed with the succession of a southern Wisconsin grassland to a forest. The composition of plant and animal communities change along with the landscape. Adapted with permission from material produced by the Minnesota Department of Natural Resources.

## ECOLOGICAL SIMPLIFICATION

Ecological simplification means that the interrelationships between organisms and their environments are reduced in number and complexity. Simplification can be caused by habitat loss, non-native species encroachment, air and water pollution, and many other factors. Although the effects of simplification are complicated and often subtle, they are often discussed in terms of their impact on the three major attributes of ecosystems: *composition, structure, and function* (Fig. 5).

## COMPOSITION

Composition refers to the fundamental elements of natural systems—the specific organisms or groups of organisms that a unit area or geographic area contains. At the statewide level it includes ecosystems, communities, species, and their genetic composition. Thus, an ecological system simplified in terms of composition might have reduced numbers of species present or a limited gene pool for a remnant or isolated species.

The most radical impacts on composition occur when there is total destruction of the biotic, abiotic, spatial, or temporal needs of species. The conversion of native